A Thermo-mechanical Stress Analysis Of An MCM-D Interconnect

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A thermo-mechanical analysis has been performed to predict temperature cycling stresses within the interconnect structure of a multichip module substrate. In particular, an MCM-D structure, implementing aluminum-silicon (Al-Si) metallization layers separated with a silicon dioxide (SiO_2) interlayer dielectric, was examined using a two-dimensional, plane-strain finite element model (FEM).

Developed with PDA/PATRAN, the FEM was configured to simulate a cross-section through a typical interconnection between metallized signal layers. Geometry for the modeled configuration was derived from scanning electron microscope photographs taken at the Jet Propulsion Laboratory. Material properties for the metallization layers were characterized with a non-linear stress-strain curve, obtained from published thin film research data.

A total stack-up thickness of 17 microns was modeled, representing, a 7 micron Si02 base, a 2 micron thick Al-Si signal layer, a 2 micron thick SiO_2 dielectric layer, a second Al-Si layer and a 4 micron Si02 passivation. The interconnecting via was given a slope of 26 degrees and a sharp corner at the signal plane transitions, as indicated in electron photomicrographs. The figure below illustrates the modeled configuration.

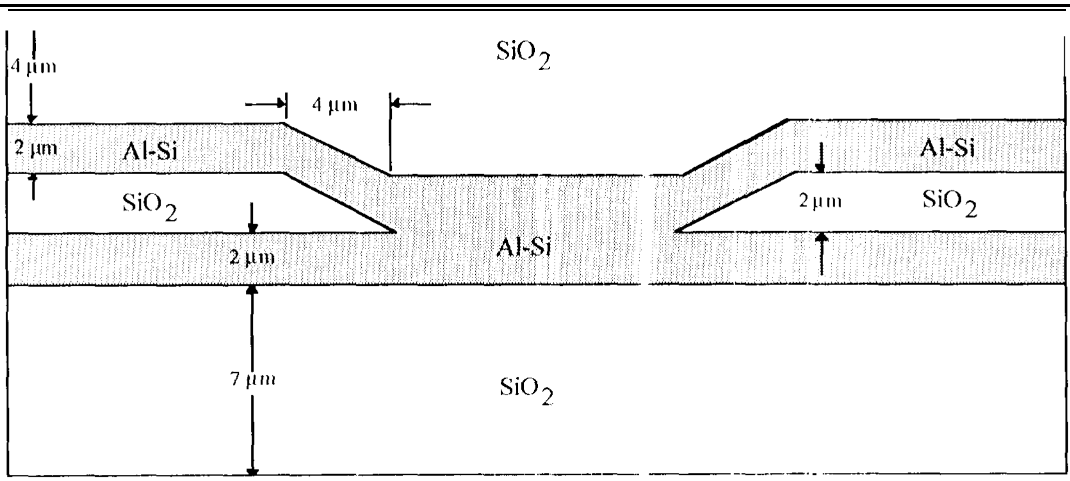

Figure - Analyzed MCM-D Substrate

The finalized FEM incorporated 702 plane strain, two-dimensional elements, connecting a total of 760 space coordinates. A vertical constraint boundary condition was placed on nodes of the base silicon dioxide layer, while a symmetry argument was invoked on the two sides. The top of the passivation layer was allowed to expand without restraint.

A temperature field was applied to the model to simulate repeated heat-up and cool-down cycling between temperatures of 20 °C and 200 °C. The resulting non-linear, elasto-plastic stress-strain response was obtained, under the assumption of a von Mists constitutive model, using MSC/NASTRAN version 67.5 as implemented on a Cray Y-M i' computer.

The observed stress-strain distribution occurred due to the mismatch in coefficients of thermal expansion (CTE) between metallized layers and the surrounding ceramics. This mismatch is considerable, with the Al-Si CTE exceeding that of the interlayer SiO_2 by a factor of 47. As a result, the Si02 acts to constrain the Al-Si, producing high shearing stresses at the material interfaces.

It should be noted that the stress mechanism found here differs significantly from that discovered in previous studies of MCM-L substrates. In the latter, metallization layers are typically surrounded by polymeric dielectrics, which expand much more than the metal. The intermetallic vias can therefore be subjected to cyclic bending rather than shear, resulting in comparatively low fatigue life.

1 n the current study, strain-based fatigue life can be predicted from the finite clement results using a Coffin-Manson relationship. Although this effort is still in progress, preliminary results indicate that the substrate should withstand thousands of cycles.

In a parallel effort within the ARPA-sponsored RELTECH program, the examined MCM-D hybrid is being subjected to continuous temperature cycling in the temperature range considered here. Thus far, test results indicate high durability for the design under cyclic temperature conditions, corroborating the fatigue predictions of this analysis.

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